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ACMS: A PROTOTYPE EXPERT DATABASE FOR AIR COMBAT MANEUVERING

by

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This study describes the design and implementation of a prototype expert database training system for air combat maneuvering. The architecture of the system integrates a rule-based expert system with a database in a loosely coupled fashion. The expert system component of the system uses its rule base, access to the database, and pilot input to arrive at its decision.

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ACMS: A Prototype Expert Database for Air Combat Maneuvering

by

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ABSTRACT

In combat situations, a fighter pilot must deal with a large number of input variables and decision alternatives in a very short time. To have the greatest chance of success in an encounter, the pilot must have a viable game plan in mind before he engages with an enemy aircraft. This game plan comes about through many hours of expert training in various scenarios of actual and hypothetical situations.

This study describes the design and implementation of a prototype expert database training system for air combat maneuvering. The architecture of the system integrates a rule-based expert system with a database in a loosely coupled fashion. The expert system component of the system uses its rule base, access to the database, and pilot input to arrive at its decision.

THESIS DISCLAIMER

The reader is cautioned that the computer program developed in this research is only a prototype and may not have been exercised for all cases of interest. This program does not address many potential aspects of the air combat maneuvering arena. While every effort has been made within the time available to ensure that the program is free of computational and logic errors, it cannot be considered validated. Any application of this program is at the user's own risk.

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I. INTRODUCTION

The Navy recognizes the need for comprehensive training of its flight crews to increase their combat effectiveness and survivability [Ref. 1:p. 1]. The area of air combat maneuvering (ACM) or dog-fighting is of particular concern for two reasons: first, the aircrew faces a much higher level of threat than is encountered in most other missions, and second, the pilot is rarely exposed to ACM in a training environment. The pilot is introduced to this environment in the late stages of flight training and may encounter it again at sporadic intervals during his career. The Navy has created several entities to meet this need for greater ACM training. Among them are: the Naval Fighter Weapons School (Top Gun), Strike University, and the Pacific and Atlantic Fleet Aggressor Squadrons. These groups support aviator training for individual squadrons and also provide tactics evaluation and evolution for carrier air wings and for the Naval aviation community.

To have the greatest chance of success in an encounter the fighter pilot must have a viable game plan in mind before he merges with an enemy aircraft. The decision on the choice of game plan must be made within minutes and sometimes seconds after the enemy either has been sighted or comes under radar contact. This game plan usually comes

about as the result of many hours of studying enemy aircraft characteristics, weapons capabilities, and offensive and defensive tactics. A great deal of information also comes from formal lectures and presentations and from informal sessions with experienced pilots on actual engagements and on hypothetical situations. From these various sources a pilot learns many tactics that may be effective in a given situation and puts them to use at the appropriate time. Since most of the expertise is concentrated within a relatively small group, the new pilot must do extensive research and sorting of data to acquire this base of knowledge or he must be fortunate enough to be able to acquire it from a proven source such as an instructor pilot.

In addition, both the new pilot and the experienced aviator must also have some method for frequent and comprehensive review of this knowledge. Currently the only reliable review method is the use of the original source--the books or the expert. The most useful books are generally classified and so are often inaccessible. They are also expensive to maintain and update. The human expert may no longer be available, or may not have the latest information.

The preceding discussion suggests that a computer-based training system that combines an expert system (ES) and a database (DB) will help solve some of the problems involved

in acquiring and maintaining the organization's base of knowledge.

A. DATABASE SYSTEMS

A database is a self-describing collection of integrated records [Ref. 2:p. 28]. It is self-describing in that it contains a description of its structure in addition to the data needed for the application. The records are integrated because they contain not only files but also a description of the relationships between the records. A database management system (DBMS) is the software that allows stored data to be integrated and manipulated so that the user can represent and retrieve it. INGRES, ORACLE, dBase, and Paradox are some of the most widely used DBMS packages.

B. EXPERT SYSTEMS

Expert systems are computer software-based systems designed to capture human expertise in a specific domain and make it usable to the non-expert. The non-expert uses the input from the decision environment and arrives at an answer to a problem. Several expert systems are currently used and many more are expected to be used in the near future. The best known is MYCIN, an expert system used by doctors to help diagnose and suggest treatments for bacterial infections. Future expert systems will be used for such diverse applications as designing buildings and testing new atomic structures.

C. EXPERT DATABASE SYSTEMS

The combination of expert systems and database management systems into an interconnected package has given rise to a new area of software called Expert Database Systems (EDS). By definition an EDS is "a system for developing applications requiring knowledge-directed processing of shared information" [Ref. 3:p. 3]. In other words, its function is to apply principles and procedures from the expert's domain of knowledge (a knowledge base) to an integrated collection of records (a database) thereby synthesizing the data within the database to a form of knowledge that the user can readily understand.

The problem encountered in integrating these two technologies lies in their basic structure. A DBMS is highly organized and requires precise syntax for storing and retrieving data. Most have somewhat limited symbolic manipulative abilities. In contrast, an expert system contains no data and instead focuses on rules and inheritance, with an emphasis on classes of data as opposed to a precisely delineated instance of data. This dichotomy can lead to several different architectures for integration. The method used depends on the function of the two subsystems within the overall system. Another consideration is the researcher's primary discipline. Database people tend to choose a DBMS driven approach and AI people tend to lean toward an ES-driven system.

The first two architectures are referred to as "coupled" since both subsystems retain their original structure and appearance. In the first, the Expert System controls the DBMS with the Expert System functioning as a front end data entry system for the database. Alternately the Database Management System can control the Expert System, with the latter performing the tasks of query optimization and selecting views of the data. A third architecture is the complete integration of the subsystems to create a "knowledge based management system" that can function as a deductive-database [Ref. 4:p. 386]. A final architecture is a master-slave relationship wherein the two subsystems alternately control each other through message passing; this allows the subsystems to act as stand-alone systems.

The requirement for an Air Combat Maneuvering System (ACMS) suggests a loosely coupled, pseudo master-slave architecture. The database component of ACMS, the Threat Fighter Database (originally the Tactical Air Threat Assessment System or TATAS) can be used as a stand-alone program while the expert system Tactics Advisor must have access to the database to have complete functionality. Since both subsystems retain their original form, it can be viewed as a loosely coupled system [Ref. 5:p. 10]. This architecture was chosen because it allows the DBMS to be accessed and maintained independent of the expert system. This was deemed desirable since the database can contain

classified information that may need to be updated frequently by intelligence personnel. To this end, access to the maintenance mechanisms in TATAS' Threat Fighter Database is controlled by a sophisticated security subsystem. The architecture also permits review of the database by pilots who are interested in aspects of enemy air forces that do not pertain to air combat maneuvering. In addition, the loose coupling lends itself to easy maintenance of the rule base when the rules need to be changed or when new ones need to be added to expand capability.

The Expert System/Database integration of ACMS is expected to make a two-fold contribution to training fleet aviators and replacement fleet aviators. First, it will greatly simplify updating and backup of important enemy aircraft information because the unit's intelligence officer will be able to access the database rapidly and make the requisite changes. When an aviator needs the most recent information on a theater, country, or aircraft, he will be able simply to use the computer rather than having to comb through many official Navy messages that may or may not have the required information or having to read publications that may not be up to date or accessible.

The second benefit to be garnered will come from the Expert System (Tactics Advisor) component of the project. The aviator will be able to access years of experience and

expertise in the field of ACM. He will come away highly confident of his extensive range of opening gambits and will know ahead of time (and with great certainty) what his best options will be when a given situation presents itself.

D. SCOPE

The purpose of this thesis is to demonstrate the feasibility of constructing an Expert Database system to train pilots for ACM engagements.

It will also address the issue of integrating an expert system and a database. Specifically included in the study will be a modification of the existing aircraft database, an interface between the expert system and the aircraft database, the user dialogue for the expert system, and the construction of the expert system rule base using the VP-Expert and dBase III+ software packages.

Chapter II provides background information detailing the decision-making process during an ACM engagement. It includes parameters and constraints that must be considered in making the decision. Chapter III briefly addresses the design and construction of the TATAS database and Chapter IV contains a discussion of the design and construction of the expert system component of ACMS. Chapter V contains the conclusions of the research and benefits, limitations, and weaknesses, of ACMS. Appendix A contains the schema and menu structure of TATAS, Appendix B the dependency diagrams

of ACMS, Appendix C contains the rule-base of ACMS, and Appendix D a session with the expert system.

II. PARAMETERS AND CONSTRAINTS OF THE DECISION

The following descriptions are based on interviews with air-to-air qualified fighter pilots from Strike Fighter Squadron 125 at Naval Air Station, LeMoore, California. Further information presented is based on personal experiences while the author was a fleet replacement pilot flying the F/A-18 Hornet at Marine Corps Air Station, Yuma, Arizona. Other facts were obtained via research in ACM tactical manuals.

Advance training is an absolute requirement for a successful ACM engagement. If a pilot can survive his first five encounters with an enemy aircraft or bogey, his chances of completing a combat tour are greatly enhanced [Ref. 6:p. 217]. To this end, Naval Fighter Weapons School trains fleet aviators in the latest tactics and with the latest information on a potential enemy's capabilities. The graduates of this school then disseminate this knowledge to other pilots in their squadrons. Since the pilot is now armed with this knowledge prior to the engagement, he will be able to make better combat decisions.

Because time is so critical during combat, a decision on how to fight the engagement must often be made within seconds. This sense of urgency is compounded by the facts that the enemy's intentions are completely unknown and that

the pilot's life and those of his comrades are in jeopardy. Added to this is the realization that the pilot has perhaps only one other ally, his wingman, with him for the next few minutes. Therefore, that the pilot make the correct first move becomes critically important. If the pilot has had advance training on what to expect in an engagement and how to approach the decision-making process, he will be able to make a more rapid and correct evaluation of the fight thereby giving him a much greater chance of success.

Unfortunately, there is no one absolutely correct choice to be made, because many variables must be evaluated before the pilot decides. Usually these variables are not easily determined and the pilot must act with less than complete information. The variables considered by the pilot in his decision-making process are broad. Constraints may also preclude his using all of the options available to him. Among these variables and constraints are:

- Friendly aircraft type and capabilities.
- Enemy aircraft type and capabilities.
- Friendly aircraft weapons loadout.
- Enemy aircraft weapons loadout (if known).
- Rules of Engagement (ROE) in effect.
- Weapons free/ Weapons tight policies.
- Relative airspeeds of aircraft involved.
- Friendly aircraft condition (fuel, damage, crew).
- Bogey information (number, formation, relative position).

- Weather conditions.
- Proximity of SAM and AAA installations.
- Method of bogey control (self, air, ground).

The decision to engage in combat is sometimes already made for the pilot. The pilot must either be prepared to enter the engagement or risk getting shot down or losing a wingman. An example of this has occurred during recent shootdowns in the Gulf of Sidra when unfriendly aircraft exhibited aggressive behavior by firing two air-to-air missiles and the aircrews responded by engaging and shooting them down. The decision on how best to enter the fight is made before the fighter and bogey pass each other. Although some snap decisions are necessary (and sometimes desirable), the pilot will usually fight a better engagement if he has carefully considered many different situations. Most fighter pilots will go over various scenarios and have ready one or two potential opening moves for each.

After the initial move on both sides, the variables start to increase exponentially. All of the pilots that were interviewed were hard-pressed to come up with second and third moves without knowing in some detail all of the parameters of the engagement after the time of the first move. Their choice of follow-up maneuvers was highly dependent on the moves of the bogey. This points up the extremely dynamic nature of ACM and the decisions that must be made during an engagement. Because some of the

information the pilot uses is classified, the description of the decision process must be somewhat circumspect. However, getting an idea of how the decision is made is simple.

As discussed earlier, the pilot's first-move decision is made before the engagement through hours of text study, course work, and interaction with other pilots. The data that the pilot uses comes in several different formats to convey varying types of information. The necessary data can be found in graph, diagram, and radar-depicted form. Through the use of tactical manuals and Fighter Weapons School publications, the pilot can get information on both his aircraft and the bogey's capabilities as well as the counter-tactics most likely to succeed against the enemy. The pilot is particularly interested in how a potential adversary's aircraft can perform. Armed with this data, the pilot can determine how his aircraft can be expected to maneuver relative to the other aircraft. The data also gives him an idea of the types of maneuvers the enemy might employ and the types of maneuvers he can use to counter an advantage held by the bogey. The data is found in what are called maneuvering graphs, and consist of best maneuvering speed, maximum G-force available, and maximum energy addition curves. Other graphs used by the pilot include shot envelopes for missiles and guns, and threat weapons parameters. The method by which this information is

simplified to a format easily used by the pilot is classified and will not be addressed here.

A third source of information used by the pilot is the fight diagram. This drawing shows the maneuvers used by each aircraft during the fight and can aid the pilot by emphasizing the moves that worked in defeating a bogey and those moves that did not work. This information is evaluated and stored to be used in a later engagement. The drawings are usually made immediately after the fight or during the debriefing session.

From the intelligence briefing, the pilot will be advised on the weapons that he can expect to encounter and on the tactics that the enemy may employ. He will also be given the various aspects of the ROE in effect such as acceptable intercept parameters and weapons firing polices for the carrier air wing. The pilot will be interested in diagramming possible intercept scenarios and his planned reactions to them.

The most important task that the pilot faces is to determine the best opening move or tactic he should use to maneuver his aircraft into a position to employ a weapon, destroy the enemy, and minimize damage to both himself and other friendly forces. Although numerous individuals may provide input to the decision-making process during an ACM engagement, the final maneuvering decision rests in the hands of the pilot. Others involved in the process are the

pilot's Radar Intercept Officer (back-seat), his wingman, the Carrier Airgroup Commander (CAG), and the air traffic controllers.

The pilot's first decision is whether he is physically capable that day of sustaining the rigors of a high-G force environment for an extended period of time. Studies have shown that individuals show day-to-day variations in their ability to withstand G forces. These variations are attributable to a number of factors including physical condition, amount of rest, nutrition, and general state of health [Ref. 7:p. 4]. A less than fully fit and healthy aviator can have an engagement that must be broken off in seconds due to a low G-tolerance.

The next consideration is the aircraft itself. The pilot must determine whether it is fully mission capable with no fuel, flight control, or weapons systems anomalies. A degraded system in these areas can lead to a vastly degraded overall fighter package which in turn can have disastrous consequences. These various systems are checked during the preflight and then again immediately after take-off. The systems are then generally monitored at various intervals during the remainder of the flight.

Once the preliminary factors are ascertained, the pilot will start taking into account factors external to his aircraft. He must determine if his wingman has a fully functional aircraft. If not, can it be fixed? If not, can

it still be used? Next he must consider how far the flight is from a friendly landing area and how far it is from enemy-controlled territory. The further from home plate he finds himself, the more conservative he must be on his fuel. If he finds himself close to enemy territory he must also now be concerned with surface to air missiles (SAMs), anti-aircraft artillery (AAA), and additional enemy bogeys. Other considerations include the method the bogeys are using to control the intercept. A ground-controlled intercept will dictate a merge that is different from one in which the bogeys are using their own aircraft's radar [Ref. 8].

Once all of these initial parameters and constraints have been taken into account, the fighter pilot is ready to consider the actual bogey. Radar depictions help the pilot to determine bogey formations and relative speed between aircraft. This information aids the pilot in moving his aircraft to a position that best places the fighter within acceptable intercept parameters or into a position from which a weapon can be effectively employed. This information is obtained from the radar scope in the aircraft or from the Navy Tactical Data System (NTDS) data link supplied by either airborne or ship-based radar.

From the radar depiction the pilot can determine how many enemy aircraft are in the formation, their positions relative to each other, and how fast they are travelling. Differences in these parameters can alter the pilot's game

plan dramatically. He also needs to determine the aircraft type and the kinds of weapons they are carrying. A fourth generation radar-equipped fighter carrying forward quarter weapons must be intercepted and fought differently from a first generation fighter with rear quarter only capability. Much of the decision also depends on the Rules Of Engagement (ROE). If the pilot is cleared to shoot beyond visual range (without actually seeing the bogey), he may never have to get close to the bogey. However, if he must get a visual identification or if he is not allowed to make a shot, he must use an appropriate strategy that will allow him to close with the bogey and not get shot down.

The final decision (for the purpose of this study) occurs at the merge and must be made rapidly and executed precisely. This decision must take into consideration all of the other previously discussed parameters, but it is based on the maneuver that the bogey makes at the pass. If the bogey elects to run straight through, the fighter may be able to let him go or the fighter may have to chase him down depending on his fleet defense responsibilities. If the bogey stays to fight, the fighter must figure out the maneuver the bogey is using and how he can best counter it. A bogey that moves vertically presents an entirely different problem than one that moves only horizontally [Ref. 9]. Since the horizontal bogey is a simpler one to quantify and to counter, this Expert System has been limited to

addressing decisions associated with an enemy that uses only horizontal maneuvers.

Once the fight has been joined, the pilot must constantly evaluate the engagement. Each new maneuver and each change in the other initial parameters will change the fighter's strategy and his chances for a successful engagement [Ref. 10]. If the fighter makes a bad evaluation or stops evaluating the fight, he could find himself in a very dangerous and perhaps fatal situation.

The Air Combat Maneuvering System is designed to be used as a computer-based training aid while in the ACM syllabus of flight school or in a fleet squadron. The system will automate the decision of which tactic the fighter should use given the tactical situation by asking the pilot to enter various facts while at the computer terminal. From these facts the system will make some intermediate decisions such as the bogey's overall fighting capability, the fighter's overall systems capability, and the suitability of the tactical environment for engaging the bogey. After the intermediate decisions are made, the ACMS will determine a recommended tactic for the fighter to use and give a brief description of it along with any warnings that apply to that particular engagement.

III. DESIGN AND IMPLEMENTATION OF TATAS DATABASE

The database component of ACMS, the Tactical Air Threat Assessment System (TATAS) Threat Fighter Database and data layouts were constructed in a previously assigned project at the Naval Postgraduate School. The database has been modified by the addition of aircraft capability fields to the aircraft records and weapon description fields to the weapon records. The database schema of TATAS is shown in Appendix A, Figure A.1.

While the TATAS database can be used as a stand-alone interactive system for aircraft threat assessment, in ACMS it constitutes the primary data source for the Tactical Advisor expert system. It contains the bogey aircraft characteristics and weapons capabilities as well as air forces data for a particular country or theater. The aircraft view contains primarily threat aircraft data as do the weapon and sensor views. The database also contains a theater view consisting of all the countries within a theater and a country view consisting of the aircraft used by a particular country. The deployed sensor and deployed weapon views contain the weapons and sensors that are used on the aircraft of a particular country.

The data is comprised of aircraft entities, country entities, weapon entities, and sensor entities. The

database model is shown in Figure A.2 in Appendix A. The Tactics Advisor extracts the performance related fields from the aircraft records and the capability related fields from the weapons records. The fields in the record are listed as the Item and the legal values for the fields are listed as the Type. The database is accessed by the Tactical Advisor through a database file interface provided by VP Expert.

IV. DESIGN AND IMPLEMENTATION OF TACTICS ADVISOR

The construction of the expert system component of ACMS, the Tactics Advisor, consisted of three phases. A diagram of the methodology is shown in Figure 4.1 below. The first phase was determining the user requirements and consisted of requirements analysis and requirements review tasks. These tasks included interviews with ACM experts, research into the current system functions and components, definition of the expert system functions to be implemented and their control mechanisms, and a review of the VP-Expert and dBase III+ software capabilities.

The second phase of the project was system design. This phase consisted of the rule base design, the modification of the database, the expert system/database interface design, and the user interface design.

The third and final phase was the expert database prototyping which consisted of the system prototype construction task and the system review task. These tasks were conducted in accordance with the previously completed requirements analysis and system design phases. This process was followed iteratively culminating in the final prototype of ACMS.

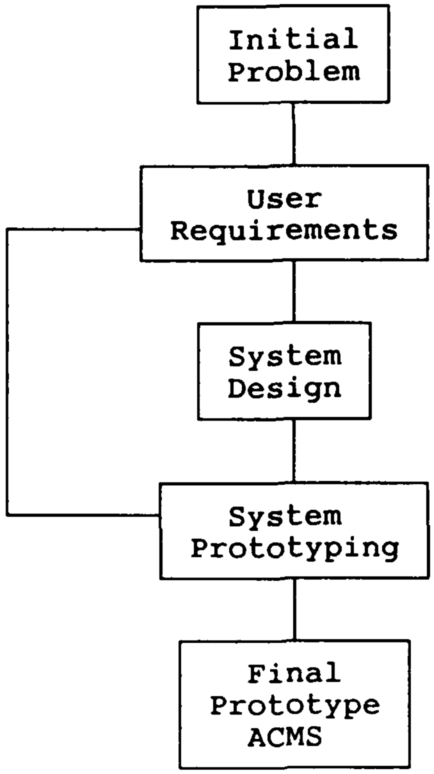

Figure 4.1 Development Methodology

A. REQUIREMENTS ANALYSIS

The methodology used in the construction of ACMS is derived from the structured situation analysis paradigm [Ref. 12]. Structured situation analysis breaks the decision-making process into knowledge segments. It determines how those segments are related and how they are used to arrive at the decision. While ACM is not a business decision, the paradigm is a very usable approach to construction of expert systems in nearly any domain. Before design and construction can begin, several areas must be

considered to ensure the feasibility of an expert system for this domain.

For an expert system to be appropriate to the problem, five conditions are required. First, there must be recognized experts in the problem domain. This condition is met. Air combat maneuvering experts can be found in the aviation community in a few places such as Navy Fighter Weapons School, Fleet Replacement Squadrons, and operational fighter and fighter/attack squadrons. The experts have far more ability in the ACM arena than a novice and most have the ability to teach their skills to a properly prepared novice. Second, the experts must agree on the tactics to be used in various situations [Ref. 9]. There are several publications which contain ACM doctrine in use by the Navy which were written by these experts. In addition, during interviews the experts gave similar tactics to use in similar situations. Third, the experts must be able to articulate the tactics in symbolic form, orally, and in written form. They are able to do this with the use of debriefs, post-flight assessments, and fight diagrams. Fourth, the task must be well understood. For example, the goal of the fighter pilot is to maneuver into a position to intercept, engage, and shoot the bogey before the bogey shoots the fighter pilot. Fifth, the task must be of manageable size if the number of parameters is properly constrained [Ref. 12:p. 37]. With proper structuring, the

parameters of the ACM environment are finite resulting in a limited number of solutions for an engagement.

The knowledge used in ACMS was acquired using problem description and problem refinement during interviews with ACM experts. Further information was obtained from the F/A-18 Tactical Manual and from Topgun publications. From these sources, the types of knowledge used to solve the problem space and how the pilots manipulate the knowledge to arrive at a decision were determined. Additionally, the various types of decisions, recommendations, and possible anomalies and how they might be encountered were examined. Most of these decision parameters were discussed in Chapter II. To facilitate the analysis process, decision tables and decision trees using the decision parameters and final recommendations were constructed. Due to the exponential expansion of the problem space with the addition of different parameters, it was decided to narrow the focus of the Expert System by limiting the number of bogeys and eliminating most of the intercept process. The narrowed focus still allowed the system to address the most typically encountered situations.

B. DESIGN

ACMS is designed to be a computer-based menu driven expert system that will support the training syllabus used by the fighter pilot in making ACM decisions. This is accomplished through the use of a database interface and a

system dialogue for user-derived data. The system will give recommendations on the best first move to use in a given encounter as well as warnings of potential hazards. ACMS is comprised of two separate, loosely coupled subsystems that are accessed through a main menu. The TATAS database subsystem contains theater, country, aircraft, weapons, and sensor data that can be viewed and edited as needed. The Tactical Advisor Subsystem contains an ACM rule base that can access the Threat Fighter Database and use this data to fire rules in the rule base to arrive at a decision for 1v1 (1 versus 1) ACM scenarios.[1] The logical system design is shown in Figure 4.2 and the dependency diagram and rule base for ACMS are contained in Appendix B.

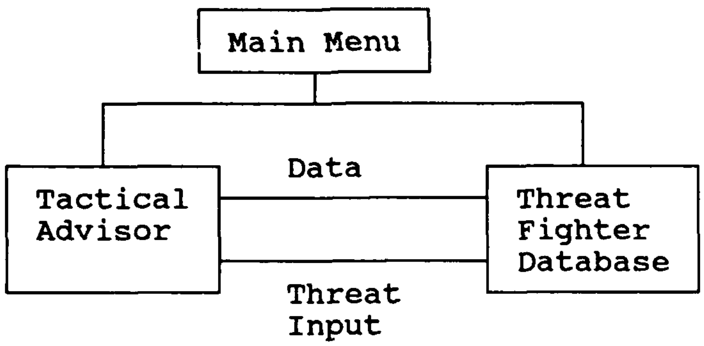

Figure 4.2 ACMS Logical Design

[1]When all of the constraints of a rule have been met, that rule is said to have fired.

1. System Dialogue

The ACMS main menu prompts the user to select either the Threat Fighter Database, the Tactical Advisor, or Quit (exit to DOS) options (see Figure 4.3).

ACMS
Main Menu

Tactical Advisor
Threat Fighter Database
Quit ACMS (exit to DOS)
Highlight item and press <return>

Figure 4.3 ACMS Main Menu

The expert system side of ACMS (the Tactical Advisor) uses a system-generated dialogue to get from the main menu to a knowledgebank access point. When the Tactical Advisor is activated, the system starts its search for an appropriate tactic by prompting the user for data input regarding his aircraft, his wingman, the tactical environment, and the aircraft he expects to encounter. Figure 4.4 shows a sample question used by the Advisor.

What type of Aircraft is the bogey?

MiG-19	MiG-21
MIG-23	MiG-29

Highlight choice and press <return>

Figure 4.4 Sample ACMS Question

The available options are presented in a menu that is created from data residing in the Threat Fighter Database. The system obtains the other parameters in a similar manner. The parameters are then checked against the database and the information required for each parameter will be extracted and used in the rule base. For instance, when the pilot enters the aircraft name, the system extracts the aircraft performance capability from the database and inserts it into the rule base.

The weapon system capability is determined in a similar manner. When the bogey missile is selected, the system accesses a weapon record in the database to retrieve the Wep_Desc (Weapon Description) field which describes it as either a forward quarter missile or a rear quarter only missile.

During the consultation the Expert System will offer warnings that are appropriate to the engagement and information that is usable for any engagement. Finally, the Tactical Advisor describes the tactic it has chosen as most appropriate. When the system has determined a recommended tactic, it will display the tactic and a confidence factor and a description of the tactic (see Figure 4.5).

The description of the tactic is contained within a TEXT file which is read and displayed by the Tactics Advisor. At the completion of each consultation, the system

The fighter should use **Tactic B** CNF 100

Tactic B is a 3 to 5 second extension followed by a pitch back or a pitch up depending on the bogey's vertical maneuver. During the extension the fighter should to strive maintain visual contact as this type of bogey is relatively small. While coming back at the bogey, the fighter should employ a forward quarter missile if weapons separation parameters are met. The tactic can be repeated as necessary.

Press any key to return to the Advisor.

Figure 4.5 Sample ACMS Conclusion

will prompt the user for additional consultations or allow him to exit the system.

2. Modeling Components

The model component of ACMS is an IF-THEN rule base contained in the Tactical Advisor subsystem. The rules were devised after extensive review of the F-18 Tactical Manual and interviews with ACM instructors from Strike Fighter Squadron 125 (VFA-125) and a Top Gun instructor at NAS LeMoore, California. Figure 4.6 shows a sample rule used by the Tactics Advisor.

```
IF      Bogey_capability = Hi AND
        System_Stat = Good AND
        Environment = Good
THEN    Fighter_Tactic = B CNF 90
```

Figure 4.6 Sample ACMS Rule

Once the decision parameters were determined they were combined into appropriate knowledge segments through the use of decision tables. For example the parameters Bogey_type, bogey_airspeed, and bogey_turn are used in finding the decision variable Corner_capability according to a set of decision rules. Weapon_name and missile_aspect make another knowledge segment called FQ_Weapon_System at the same level as Corner_capability. These two decision variables are then combined according to a different set of rules to get the decision variable Bogey_Capability shown in Figure 4.6 above. The same process is used for the decision variables System_Stat and Environment. The dependency diagram for the Expert System can be constructed when all of the decision parameters and variables have been decided upon. The dependency diagram shows their interrelationships and the reasoning process that is used in arriving at a decision. The ACMS dependency diagram is shown in Appendix B.

The rule base has been modified in the interest of security and therefore does not give absolutely correct advice, nor does it use the inputs that would be of the greatest interest to the pilot; however, the system does demonstrate the integration of an expert system with a database and demonstrates the potential for further development in this field. At present the rule base is composed of about 100 rules pertaining to ACM and twenty

five pertaining to data acquisition and decision output. To be fully implemented and integrated with the Pilot's Associate, the rule base would realistically need to be expanded to at least 5000 rules for ACM with another 500 needed for data input.

3. Control Mechanisms

The main control mechanism for ACMS is the opening menu which allows the user to select the portion of the system that he needs. The choices are limited to the Threat Fighter Database, the Tactical Advisor, and a Quit routine.

A majority of the control mechanisms are contained within the Threat Fighter Database. These mechanisms consist of the menus used to move about within the database. The system is designed with sub-menus giving the user options to use the various portions of the database. These menus allow the user to select the data that is needed and the user is then guided step by step through the necessary procedures to get the information he seeks or to edit any data that requires an update [Ref. 13].

The Tactical Advisor uses options extracted from the database for each selection so a user will not be able to make an illegal input. The control mechanisms allow the pilot to view only those aircraft that have been added to the database by competent authority. Additionally, the user can ask "what if" questions to change parameters and see how these changes alter the decision. The shell also contains

an on-line help subsystem that can be accessed as necessary. Finally, the user can query the rule base with HOW and WHY commands to determine how an answer was reached and why a particular question was asked.

C. CONSTRUCTION

The rule base was constructed by translating the previously determined constraints and variables into If-Then rules that were syntactically correct for VP-Expert.

1. Hardware/Software Requirements

The two component systems of ACMS were developed on an IBM PC with two floppy drives and a 30M internal hard drive. The entire system could be run on a two floppy system but the most efficient set up would be a 10M internal drive for the executable code and floppy disks for the files and rulebase to maintain acceptable security standards. The database was written in dBase III+ and requires 283k bytes compiled and 123k bytes uncompiled. The various data and index files require 27k. The expert system was written with the VP-Expert shell. The executable code requires 31k of memory and the rule base requires 37k. To comply with Department of Defense software standardization requirements, both systems would have to be rewritten in the ADA language. While this is possible, it would defeat the purpose of using a expert shells and add needless time and expense to the development of the system.

2. Installation

The installation can easily be accomplished in existing F-18 Fleet Replacement Squadrons. These training squadrons already use computer-aided instruction for much of their introductory syllabus. The squadron training and operations officers would need to review the software and when satisfied with its performance could then integrate it into the existing air-to-air computer syllabus. Since most Navy squadrons have personal computers available, ACMS could be implemented immediately following command approval with no integration into the existing computer syllabus required.

The next phase of the implementation process would be training the pilots in ACMS functions and use. The intelligence officer will also need training on the maintenance of TATAS database. The final implementation phase is the introduction of ACMS into the squadron's training routine by the training officer (acting as change agent) using parallel conversion techniques.

At present no Specific Decision Support System (SDSS) is installed in any operational combat aircraft. Many systems act in an advisory role to the pilot, but they provide only data and it is up to him to synthesize the information from the data. In a future role, ACMS can be a true aircraft-carried DSS by using inputs from various sensors and an interface into a new technology that is known as the Pilot's Associate. The Pilot's Associate is an

advisory system within the aircraft that monitors the systems and sensors and can be called upon to give the pilot advice, warn of potential problems and dangers, and give routine system status reports. Since ACMS is a software system it can be installed and updated by maintenance personnel as necessary.

The implementation of ACMS into the Pilot's Associate will require extensive modification of both the Tactics Advisor and the Threat Fighter Database. The quick pace of technological change makes envisioning how or estimating when this implementation could occur difficult.

V. CONCLUSIONS AND RECOMMENDATIONS

A. BENEFITS

This study has addressed the problem of expert system and database system integration into an expert database. It has also addressed the problem of ACM expertise retention and dissemination in Navy squadrons. In exploring these problems a prototype expert database was constructed. The prototype demonstrated the premise that loose coupling was a feasible solution for interfacing the two component systems. The protctype also proved to be a valid vehicle for storing ACM expertise and making the knowledge easily accessible.

Use of an expert shell with an If-Then rule construct proved to be an efficient method to model the expertise. The shell also appeared to be much easier to use in building the system than the use of an artificial intelligence language such as LISP or Prolog.

The menu-driven system is easy to use even for those with very little experience with computers. The only computer knowledge required is how to get the program started. Once this has been accomplished, the user needs only to follow the menus and directions as they appear on the screen to get full use of the system. In its current state, ACMS will be used by pilots as a training device in advanced flight training squadrons and in fleet replacement

squadrons. The user will be required to give input data concerning a made-up scenario and the system will then give its best option for an opening maneuver. By altering the scenarios the pilot can augment the information gained from lectures and tactical manuals and address scenarios that may not have been covered by his sources. This ability to rapidly access information on multiple scenarios will allow the pilot to more easily assimilate the tactics and guidelines upon which his success will depend.

B. LIMITATIONS AND IMPROVEMENTS

This system was designed to be a prototype and will by definition have some limitations. The number of scenarios was limited to keep the rule base size within reasonable limits. The number of input parameters was also limited for the same reason. Because the system has been "sanitized" due to security considerations, it will give only generic advice about ACM maneuvers. Another related weakness is the limitation on the number of enemy and friendly aircraft. Today's tactics call for mutual support among fighters and it should be expected that an enemy will send up more than one aircraft also. Another consideration is response time. If the system were to become a real-time system, the five or so seconds required to receive advice may be too long.

Accessing the data files in the database through the expert system proved to be a simple matter using the facilities available in the VP-Expert software package.

Some difficulties, however, were encountered when attempting to run a compiled dBase program from the Expert System due to memory limits. These difficulties limit the ability of the Expert System to use the capabilities of the DBMS to effectively manipulate the database files and perform join operations on them. This is unfortunate since the DBMS is designed to optimize data access functions.

The expansion of the rule base would address some of the limitations cited above. The number of scenarios could be increased by adding a vertically maneuvering bogey and an obliquely moving bogey. Another valuable addition would be a module in the rule base to add more data pertaining to a friendly wingman as well as multiple bogey scenarios. A surface to air missile threat module would also be a realistic and usable addition. The rule base should also be modified to output the proper advice for a given situation. The response time problem can be addressed by the use of a higher speed processor if efficiency becomes an issue. The limitation on calling a DBMS program from the Expert System could be solved by using more RAM or by using later versions of VP-Expert with better memory management schemes.

APPENDIX A

TATAS DATABASE STRUCTURE

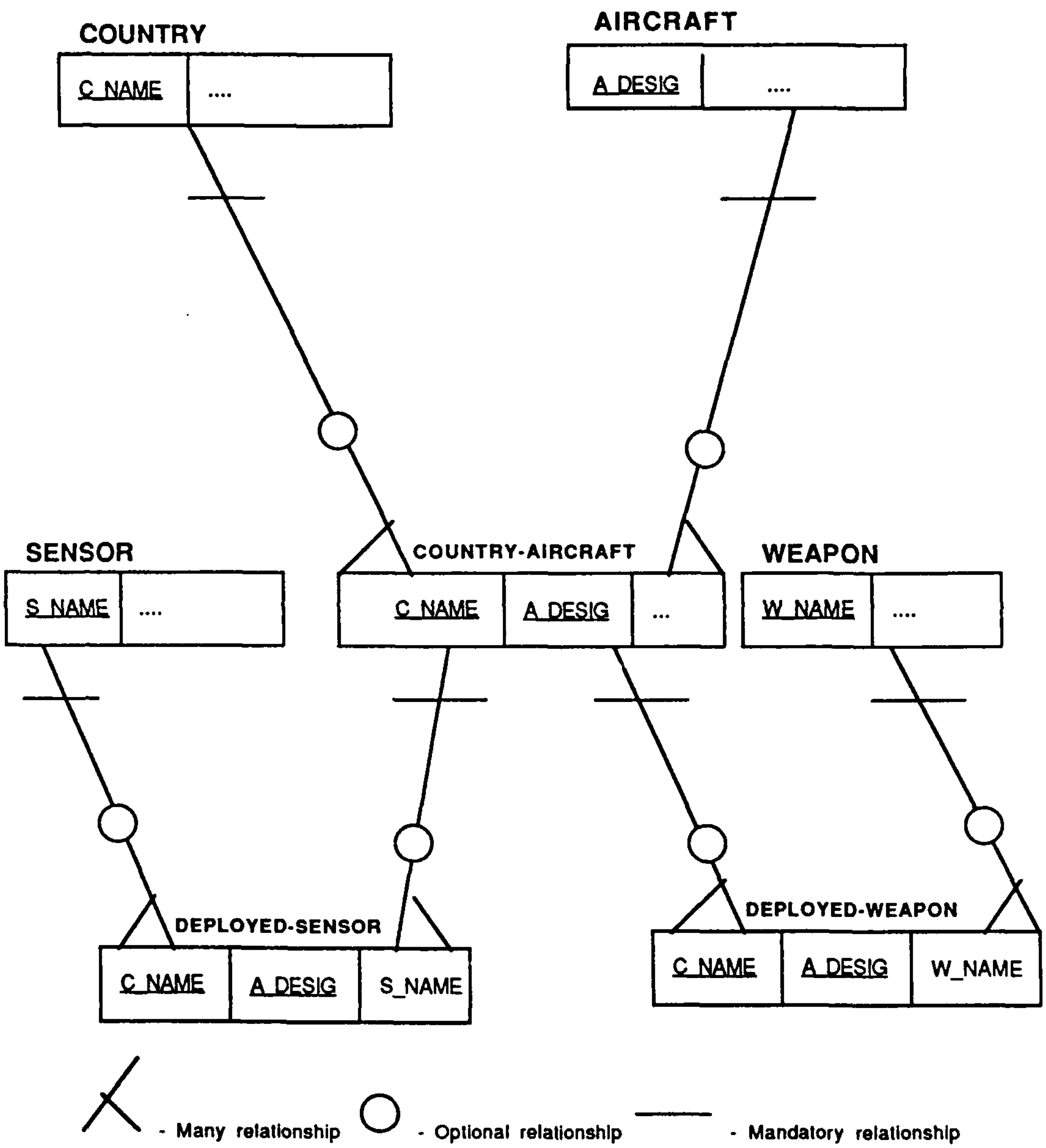

Figure A.1 TATAS Database Schema

COUNTRY

Item	Type
C_Name	A
T_Name	A

SENSOR

Item	Type
S_Name	A/N
S_Funct	A
S_Type	A
S_Desc	A/N

DEPLOYED WEAPON

Item	Type
C_Name	A
A_Design	A/N
W_Name	A/N

AIRCRAFT

Item	Type
A_Design	A/N
A_Name	A/N
A_Class	A
A_Origin	A
A_Ceiling	N
A_Genrat	A

DEPLOYED SENSOR

Item	Type
C_Name	A
A_Design	A/N
S_Name	A/N

COUNTRY-AIRCRAFT

Item	Type
C_Name	A
A_Design	A/N
Number	N

WEAPON

Item	Type
W_Name	A/N
W_Type	A
W_Desc	A/N

A - Alphabetical
N - Numerical
A/N - Alphanumeric

Figure A.2 TATAS Data Model

APPENDIX B

ACMS EXPERT SYSTEM STRUCTURE

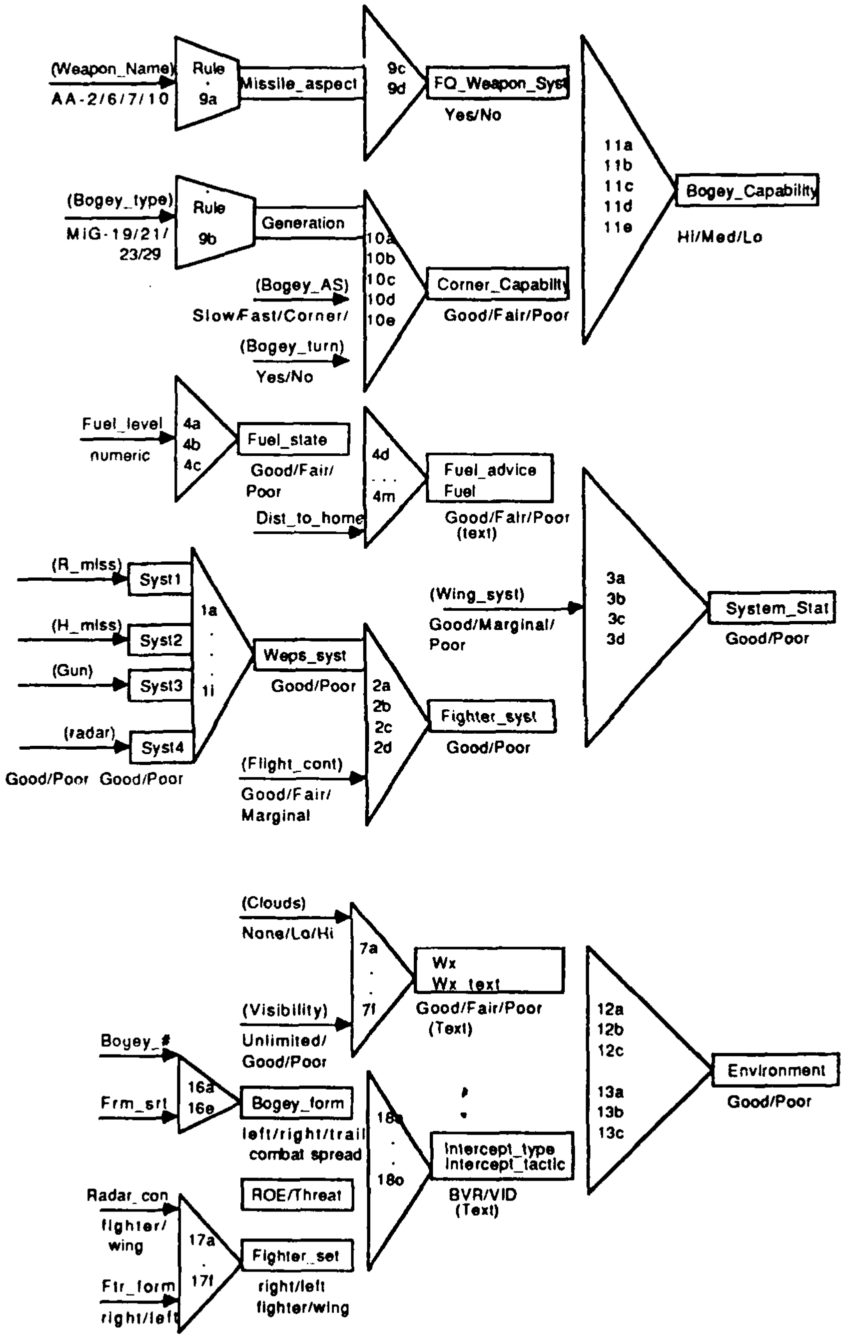

Figure B.1 ACMS Dependency Diagram 1

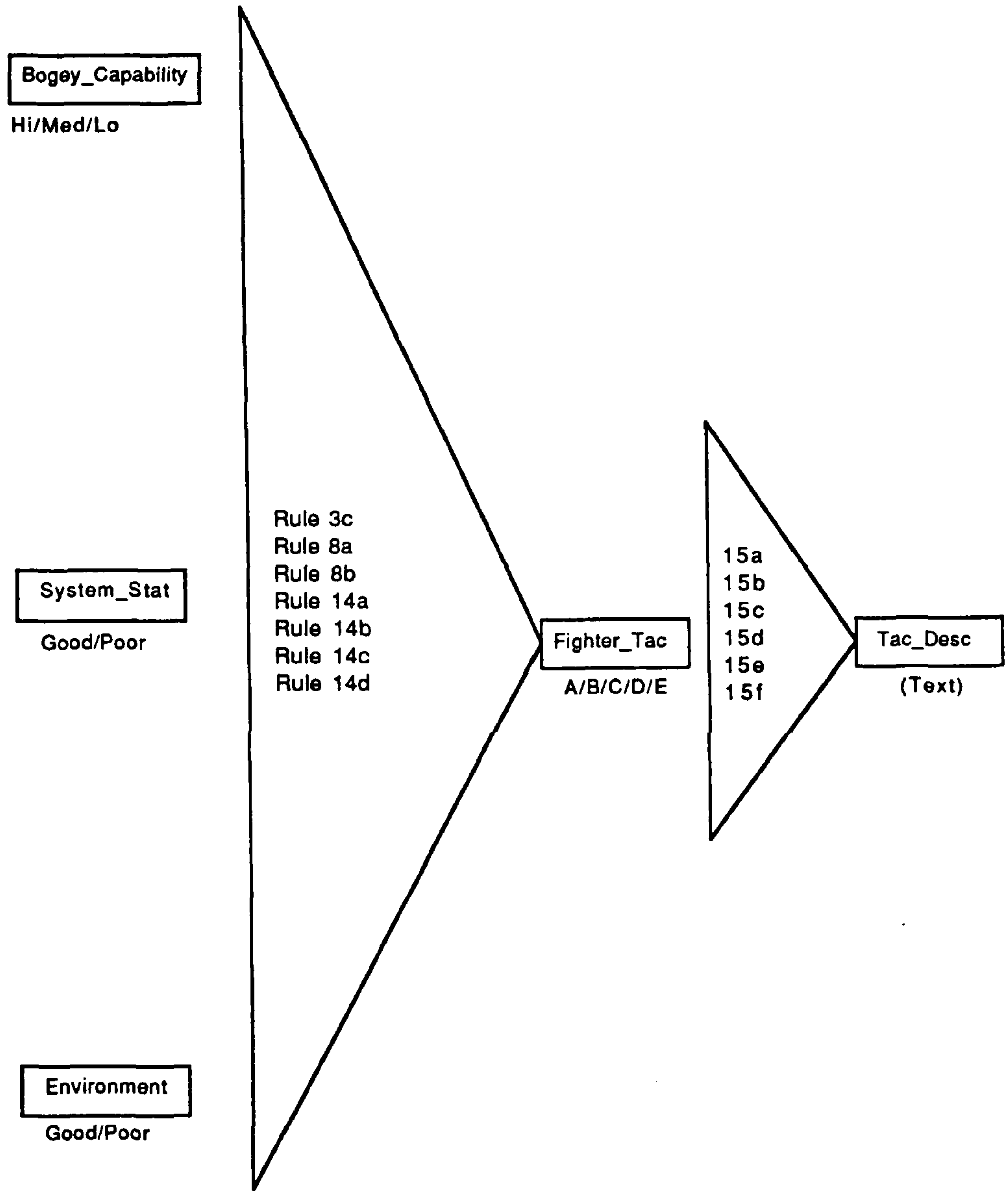

Figure B.2 ACMS Dependency Diagram 2

APPENDIX C

ACMS RULE-BASE

```
!ACMS: Air Combat Maneuvering System
!By Rod W. Lekey
!Naval Postgraduate School, 1989
!
!This program is a prototype expert system designed
!to be used as a computer based training aid
!in the ACM arena.  It has been designed to
!comply with certain security precautions and
!therefore does NOT necessarily give absolutely
!correct advice nor does it use the same exact
!criteria that a fighter would use.  Its main
!purpose is to demonstrate expert system and
!database integration. It will give a pilot generic
!advice on a maneuver to use when encountering
!a specific bogey, the best method of intercept,
!and any warnings that apply to the conditions
!in the tactical environment at the time


!This section is the main command section for
!VP Expert and tells the program the specific
!conclusions to look for and to output

RUNTIME;
EXECUTE;
BKCOLOR = 1;


ACTIONS

      COLOR = 7
      DISPLAY"

      WELCOME TO THE Air Combat Maneuvering SYSTEM

ACMS has two subsystems that can be used in conjunction.
The ACMS Tactics Advisor is a VP Expert rule base that can
be used as a training aid in the ACM arena.  The Advisor
will aid in determining an appropriate ACM tactic for a
given situation.  Due to security considerations it is
limited in scope.  A series of questions will be asked and a
menu of responses will be shown.  To make a response you
will need to move the light bar to your choice by using the
arrow keys, then press the ENTER key, and then press the End
key.

The system will do the rest
```

```
The Fighter Database is a dBase III+ constructed database
containing information on theaters, countries, air forces,
fighters, and weapons systems.  It is also used by the
Tactics Advisor in determining a tactic to use.

Press the ENTER key to start the consultation.~
"

!This section is the actions of the program
!It is the mechanism that tells the progam
!what values to find and how to get to a decision


      Exit? = No
      WHILETRUE Exit? = No THEN

            FIND User_Choice
            FIND next_action

            COLOR = 4

            RESET ALL     !Resets the variables
            COLOR = 7
            RESET Exit?   !Starts the loop again
            FIND Exit?
        END

            DISPLAY "
Press the Q key to exit the shell";


RULE 0a
IF       User_Choice = Fighter_Database
THEN     CALL c:pilot2,""
         next_action = yes;

RULE 0b
IF       User_Choice = ACMS_Tactics_Advisor
THEN     FIND Syst_stat
         FIND Fuel_advice
         FIND Wx_text
         FIND Wx
         FIND Threat_level
         FIND Intercept_tactic
         FIND Tac_Desc
         next_action = yes;

RULE 0c
IF       User_Choice = QUIT
THEN     next_action = no;
```

```
!This section is used to check
!weapons systems of the fighter
!and determine the overall weapon
!system capability

RULE 1a
IF      radar_missile = Good OR
        radar_missile = Marginal
THEN    Syst1 = Good
ELSE    Weps_syst = Poor
BECAUSE "It is necessary to determine the radar missile's
capability to ascertain the type of engagement
the fighter can be expected to fight with a
reasonable chance of success.  A poor radar missile
will usually preclude a BVR shot";

RULE 1b
IF      heat_missile = Good
THEN    Syst2 = Good
ELSE    Weps_syst = Poor
BECAUSE "It is necessary to determine the heat missile's
capability to ascertain the type of engagement
the fighter can be expected to fight with a
reasonable chance of success.  A poor heat missile
will usually preclude a short range stern shot";


RULE 1c
IF       heat_missile = Marginal AND
         radar_missile = Marginal
THEN     Weps_syst = Poor
BECAUSE "If both missile systems are marginal, the
overall capability of the fighter is greatly reduced";

RULE 1d
IF       heat_missile = Marginal AND
         radar_missile = Poor
THEN     Weps_syst = Poor
BECAUSE "If both missile systems are marginal, the
overall capability of the fighter is greatly reduced";

RULE 1e
IF       heat_missile = Poor AND
         radar_missile = Poor
THEN     Weps_syst = Poor
BECAUSE "If both missile systems are marginal, the
overall capability of the fighter is greatly reduced";
```

```
RULE 1f
IF      heat_missile = Poor AND
        radar_missile = Marginal
THEN    Weps_syst = Poor
BECAUSE "If both missile systems are marginal, the
overall capability of the fighter is greatly reduced";

RULE 1g
IF      gun = Good OR
        gun = Marginal
THEN    Syst3 = Good
ELSE    Weps_syst = Poor
BECAUSE "The capability of the Hornet gun is such
that even a marginal system is usually adequate";

RULE 1h
IF      radar = Good OR
        radar = Marginal
THEN    Syst4 = Good
ELSE    Weps_syst = Poor
BECAUSE "The radar must be in satisfactory shape
to determine the type of intercept tactic
to use on the bogey and to get a missile
shot in some instances";

RULE 1i
IF      Syst1 = Good AND
        Syst2 = Good AND
        Syst3 = Good AND
        Syst4 = Good
THEN    Weps_syst = Good
BECAUSE "In order to have an adequate weapons
system all component systems must have
adequate capability";

RULE 2a
IF      Weps_syst = Good AND
        Flight_cont = Good
THEN    Fighter_syst = Good
BECAUSE "The fighter must have adequate flight
controls in order to have an overall
capable system";

RULE 2b
IF      Weps_syst = Good AND
        Flight_cont = Marginal
THEN    Fighter_syst = Poor
BECAUSE "The fighter must have adequate flight
controls in order to have an overall
capable system";
```

```
RULE 2c
IF      Weps_syst = Good AND
        Flight_cont = Fair
THEN    Fighter_syst = Poor
BECAUSE "The fighter must have adequate flight
controls in order to have an overall
capable system";


RULE 2d
IF      Weps_syst = Poor
THEN    Fighter_syst = Poor
BECAUSE "The fighter must have adequate flight
controls in order to have an overall
capable system";



!This section checks the wingman's
!overall capability and acts as a
!stub for future expansion

RULE 3a
IF      Fighter_syst = Good AND
        Wing_syst = Good
THEN    Syst_stat = Good
BECAUSE "With a marginal wing aircraft
some intercepts cannot be run";

RULE 3b
IF      Fighter_syst = Good AND
        Wing_syst = Marginal
THEN    Syst_stat = Poor
BECAUSE "With a marginal wing aircraft
some intercepts cannot be run";

RULE 3c
IF      Fighter_syst = Good AND
        Wing_syst = Poor
THEN    Syst_stat = Poor
BECAUSE "With a marginal wing aircraft
some intercepts cannot be run";



!Rule 3d is used to keep a
!less than capable fighter
!and wingman from getting
!to a bogey encounter
```

```
RULE 3d
IF Syst_stat <> Good OR
   Fighter_syst <> Good
THEN Fighter_Tactic = F
     Fuel_advice = No
     Wx_text = No
     Intercept_tactic = None
     Threat_level = None
BECAUSE "With a marginal wing aircraft
some intercepts cannot be run and the
chances of success are reduced with an
overall marginal system";



!This section checks the fuel
!state of the flight and issues
!a warning if it is low enough to
!constitute a danger.  For future
!expansion it should include an entry
!for distance to homeplate to determine
!the flight's real fuel requirements

RULE 4a
IF     Fuel_state >= 5000
THEN   Fuel = Good
BECAUSE "A fuel state of 5000 pounds or more
is usually enough to get within shot parameters
with enough left over to get to homeplate";

RULE 4b
IF     Fuel_state < 5000 AND
       Fuel_state >= 3000
THEN   Fuel = Marginal
BECAUSE "A fuel state in this range can lead
a pilot to be overconfident in the amount of
time he actually has to fight";

RULE 4c
IF     Fuel_state < 3000
THEN   Fuel = Poor
BECAUSE "An extremely low fuel state can lead to
a flameout during actual combat";


RULE 4d
IF     Fuel = Poor AND
       Dist_to_homeplate = More_than_200
THEN   Fuel_advice = YES
       DISPLAY"
```

```
Extreme caution should be used in engaging the bogey since
your fuel state is critical.  You should not engage the
bogey unless absolutely necessary.  The risk of fuel
starvation is extremely likely.  Close coordination with
your wingman and a tanker are necessary to prevent an
emergency fuel situation
";


RULE 4e
IF      Fuel = Marginal AND
        Dist_to_homeplate = More_than_200
THEN    Fuel_advice = YES
        DISPLAY"
Extreme caution should be used in engaging the bogey since
your fuel state is critical.  Coordination with a tanker
is advisable.
";


RULE 4f
IF      Fuel = Good AND
        Dist_to_homeplate = More_than_200
THEN    Fuel_advice = YES
        DISPLAY"
Caution should be exercised when engaging the bogey since
the distance to homeplate is so great.  Your fuel state
should be monitored closely.
";

RULE 4g
IF      Fuel = Good AND
        Dist_to_homeplate = 100_to_200
THEN    Fuel_advice = YES
        DISPLAY"
Caution should be exercised when engaging the bogey since
the distance to homeplate is so great.  Your fuel state
should be monitored closely.
";


RULE 4h
IF      Fuel = Marginal AND
        Dist_to_homeplate = 100_to_200
THEN    Fuel_advice = YES
        DISPLAY"
Extreme caution should be used in engaging the bogey since
your fuel state is critical.  Coordination with a tanker
is advisable.
";
```

```
RULE 4i
IF      Fuel = Poor AND
        Dist_to_homeplate = 100_to_200
THEN    Fuel_advice = YES
        DISPLAY"
Extreme caution should be used in engaging the bogey since
your fuel state is critical.  Coordination with a tanker
is advisable.
";


RULE 4j
IF      Fuel = Marginal AND
        Dist_to_homeplate = 50_to_100
THEN    Fuel_advice = YES
        DISPLAY"
Caution should be exercised when engaging the bogey since
the distance to homeplate is so great.  Your fuel state
should be monitored closely.
";


RULE 4k
IF      Fuel = Poor AND
        Dist_to_homeplate = 50_to_100
THEN    Fuel_advice = YES
        DISPLAY"
Extreme caution should be used in engaging the bogey since
your fuel state is critical.  Coordination with a tanker
is advisable.
";

RULE 4l
IF      Fuel = Poor AND
        Dist_to_homeplate = Less_than_50
THEN    Fuel_advice = YES
        DISPLAY"
Extreme caution should be used in engaging the bogey since
your fuel state is critical.  Coordination with a tanker
is advisable.
";

RULE 4m
IF      Fuel = Good AND
        Dist_to_homeplate = 50_to_100
THEN    Fuel_advice = No;

RULE 4n
IF      Fuel = Good OR
        Fuel = Marginal AND
        Dist_to_homeplate = Less_than_50
THEN    Fuel_advice = No;
```

```
!This section checks the tactical
!environment for hi or lo threat level
!by determining the enemy posture in
!the area

RULE 5a
IF    missile_launch = yes
THEN  Threat_level = Hi
BECAUSE "If a missile has been launched in the
area it is very likely to be tracking on the
fighter or his wingman";

RULE 5b
IF    bogeys_sighted = yes
THEN  Threat_level = Hi
BECAUSE "If other bogeys are in the area, the
chances of being sighted or having a collision
are greatly enhanced";

RULE 5c
IF    triple_a = yes
THEN  Threat_level = Hi
BECAUSE "AAA and SAMs constitute an extreme danger
to the fighter and his wingman";

RULE 5d
IF    Bogey_control = Airborne OR
      Bogey_control = Ground
THEN  Threat_level = Hi
BECAUSE "If the bogey is controlled by an external
agency, it is much easier for the enemy to
vector other aircraft to the area";

RULE 5e
IF    Threat_level <> Hi
THEN  Threat_level = Lo
BECAUSE "If none of the above conditions hold
the threat is greatly reduced";

!This section determines the method
!of intercept that the fighter should
!use to close with the bogey

RULE 6a
IF    Threat_level = Lo AND
      Number_of_Bogeys < 2
THEN  Intercept_type = VID
BECAUSE "In a low threat environment, it is
unlikely that a beyond visual range ROE will
be in effect.  It will also help to preclude
accidental shoot-downs";
```

```
RULE 6b
IF    Rules_of_Engagement = VID AND
      Number_of_Bogeys < 2
THEN  Intercept_type = VID
BECAUSE "If the ROE is VID a visual identification
must be obtained before taking a shot";


RULE 6c
IF    Threat_level = Hi AND
      Rules_of_Engagement = BVR
THEN  Intercept_type = BVR
BECAUSE "In a high threat environment with a
beyond visual range ROE, it is likely that any
contact along the threat axis is an enemy aircraft";


!This section is used to determine the formation
!the bogeys are using

RULE 16a
IF    Number_of_Bogeys > 2
THEN  DISPLAY "This system is designed for 1 or 2 bogeys
and will treat any formation as 2 bogeys.  It contains a
stub for further expansion to accomadate more bogeys in
the future"
      Number_of_Bogeys = 2;

RULE 16b
IF    Number_of_Bogeys = 2 AND
      Form_sort = Stacked_Left
THEN  Bogey_formation = Stacked_Left;

RULE 16c
IF    Number_of_Bogeys = 2 AND
      Form_sort = Stacked_Right
THEN  Bogey_formation = Stacked_Right;

RULE 16d
IF    Number_of_Bogeys = 2 AND
      Form_sort = Trail
THEN  Bogey_formation = Trail;
RULE 16e
IF    Number_of_Bogeys = 2 AND
      Form_sort = Combat_Spread
THEN  Bogey_formation = Combat_Spread;


!This section is used to determine who has
!radar contact and the formation the fighters
!are using.
```

```
RULE 17a
IF     Radar_contact = Fighter AND
       Fighter_form = Right
THEN   Fighter_setup = Fighter_Right;


RULE 17b
IF     Radar_contact = Fighter AND
       Fighter_form = Left
THEN   Fighter_setup = Fighter_Left;


RULE 17c
IF     Radar_contact = Wing AND
       Fighter_form = Right
THEN   Fighter_setup = Wing_Right;


RULE 17d
IF     Radar_contact = Wing AND
       Fighter_form = Left
THEN   Fighter_setup = Wing_Left;


RULE 17e
IF     Radar_contact = Both AND
       Fighter_form = Left
THEN   Fighter_setup = Fighter_Left;


RULE 17f
IF     Radar_contact = Both AND
       Fighter_form = Right
THEN   Fighter_setup = Fighter_Right;


!This section is used to determine the type
!of intercept to be used when there is more
!than one bogey


RULE 18a
IF      Bogey_formation = Stacked_Left AND
        Fighter_setup = Fighter_Right
THEN    DISPLAY "The fighter should be the eyeball and the
wingman should be the shooter.  The shooter needs to get
radar contact as soon as possible with the help of the
eyeball if necessary.
"
        Intercept_type = VID
        Intercept_tactic = eyeball;
```

```
RULE 18b
IF      Bogey_formation = Stacked_Left AND
        Fighter_setup = Fighter_Left
THEN    DISPLAY "The fighter should be the eyeball and the
wingman should cross over to the opposite of the eyeball and
become the shooter.  The wingman needs to get radar contact
as soon as possible with the help of the eyeball if
necessary.
"
        Intercept_type = VID
        Intercept_tactic = eyeball;


RULE 18c
IF      Bogey_formation = Stacked_Left AND
        Fighter_setup = Wing_Right
THEN    DISPLAY "The  formation of fighters should perform
a shackle making the wingman the eyeball and the fighter
becomes the shooter.  The shooter needs to get radar contact
as soon as possible with the help of the eyeball if
necessary.
"
        Intercept_type = VID
        Intercept_tactic = eyeball;


RULE 18d
IF      Bogey_formation = Stacked_Left AND
        Fighter_setup = Wing_Left
THEN    DISPLAY "The wingman should be the eyeball and the
fighter should be the shooter.  The formation needs to
take a hard turn to the right to get to good intercept
position.  The shooter needs to get radar contact
as soon as possible with the help of the eyeball
if necessary.
"
        Intercept_type = VID
        Intercept_tactic = eyeball;


RULE 18d
IF      Bogey_formation = Stacked_Right AND
        Fighter_setup = Fighter_Right
THEN    DISPLAY "The fighter should be the eyeball and the
wingman
should be the shooter.  The shooter should perform a
cross under to get to a good shot position.  The shooter
needs to get radar contact as soon as possible with the
help of the eyeball if necessary.
"
        Intercept_type = VID
        Intercept_tactic = eyeball;
```

```
RULE 18e
IF      Bogey_formation = Stacked_Right AND
        Fighter_setup = Fighter_Left
THEN    DISPLAY "The fighter should be the eyeball and the
wingman
should be the shooter.  The shooter needs to get
radar contact as soon as possible with the help of
the eyeball if necessary.
"
        Intercept_type = VID
        Intercept_tactic = eyeball;


RULE 18f
IF      Bogey_formation = Stacked_Right AND
        Fighter_setup = Wing_Right
THEN    DISPLAY "The wingman should be the eyeball and the
fighter should be the shooter.  The formation
should make a hard turn left to get to a good
intercept  position.  The shooter needs to get
radar contact as soon as possible with the
help of the eyeball if necessary.
"
        Intercept_type = VID
        Intercept_tactic = eyeball;


RULE 18g
IF      Bogey_formation = Stacked_Right AND
        Fighter_setup = Wing_Left
THEN    DISPLAY "The  formation of fighters should perform
a shackle making the wingman the eyeball and the fighter
becomes the shooter.  The shooter needs to get radar contact
as soon as possible with the help of the eyeball if
necessary.
"
        Intercept_type = VID
        Intercept_tactic = eyeball;


RULE 18h
IF      Bogey_formation = Trail AND
        Fighter_setup = Fighter_Right
THEN    DISPLAY "The fighter should be the eyeball and the
wingman should be the shooter.  The shooter
needs to get radar contact as soon as possible
with the help of the eyeball if necessary.
"
        Intercept_type = VID
        Intercept_tactic = eyeball;
```

```
RULE 18i
IF      Bogey_formation = Trail AND
        Fighter_setup = Fighter_Left
THEN    DISPLAY "The fighter should be the eyeball and the
wingman should be the shooter.  The shooter
needs to get radar contact as soon as possible
with the help of the eyeball if necessary.
"
        Intercept_type = VID
        Intercept_tactic = eyeball;


RULE 18j
IF      Bogey_formation = Trail AND
        Fighter_setup = Wing_Right
THEN    DISPLAY "The formation should perform a shackle
making wingman the eyeball and the fighter
shooter.  The shooter needs to get radar contact
as soon as possible with the help of the
eyeball if necessary.
"
        Intercept_type = VID
        Intercept_tactic = eyeball;


RULE 18k
IF      Bogey_formation = Trail AND
        Fighter_setup = Wing_Left
THEN    DISPLAY "The formation should perform a shackle
making wingman the eyeball and the fighter
shooter.  The shooter needs to get radar contact
as soon as possible with the help of the
eyeball if necessary.
"
        Intercept_type = VID
        Intercept_tactic = eyeball;


RULE 18l
IF      Bogey_formation = Combat_Spread AND
        Fighter_setup = Fighter_Right
THEN    DISPLAY "The fighter should be the eyeball
and the wingman should be the shooter.
The shooter needs to get radar contact
as soon as possible with the help of the
eyeball if necessary.
"
        Intercept_type = VID
        Intercept_tactic = eyeball;
```

```
RULE 18m
IF      Bogey_formation = Combat_Spread AND
        Fighter_setup = Fighter_Left
THEN    DISPLAY "The fighter should be the eyeball
and the wingman should perform a
crossunder to the eyeball's right
to become the shooter.
The shooter needs to get radar contact
as soon as possible with the help of the
eyeball if necessary.
"
        Intercept_type = VID
        Intercept_tactic = eyeball;


RULE 18n
IF      Bogey_formation = Combat_Spread AND
        Fighter_setup = Wing_Right
THEN    DISPLAY "The wingman should be the eyeball
and the fighter should be the shooter.
The wingman should maneuver the formation
into a position to effect the intercept.
The shooter needs to get radar contact
as soon as possible with the help of the
eyeball if necessary.
"
        Intercept_type = VID
        Intercept_tactic = eyeball;


RULE 18o
IF      Bogey_formation = Combat_Spread AND
        Fighter_setup = Wing_Left
THEN    DISPLAY "The wingman should be the eyeball
and the fighter should be the shooter.
The wingman should maneuver the formation
into a position to effect the intercept.
The shooter needs to get radar contact
as soon as possible with the help of the
eyeball if necessary.
"
        Intercept_type = VID
        Intercept_tactic = eyeball;



!This section determines the weather conditions
!and gives warnings in dangerous conditions as
!well as methods of using the conditions to the
!fighter's advantage
```

```
RULE 7a
IF     Clouds = Low_Cloud_Deck AND
       Visibility = Unlimited
THEN   Wx_text = yes
       Wx = Fair
       DISPLAY "
Use the sun to your advantage while attacking by keeping
between it and the bogey if possible.  For low clouds
good altitude scan discipline must be exercised in
order to maintain adequate ground clearance.
"
BECAUSE "To determine the weather conditions and
issue appropriate warnings, the cloud deck and
visibility must be ascertained";


RULE 7b
IF     Clouds = Low_Cloud_Deck AND
       Visibility = Good
THEN   Wx_text = yes
       Wx = Fair
       DISPLAY "
Use the sun to your advantage while attacking by keeping
between it and the bogey if possible.  For low clouds
good altitude scan discipline must be exercised in
order to maintain adequate ground clearance. A good scan
is mandatory to aid in detecting inbound bogeys as early
as possible
"
BECAUSE "To determine the weather conditions and
issue appropriate warnings, the cloud deck and
visibility must be ascertained";


RULE 7c
IF     Clouds = None AND
       Visibility = Good
THEN   Wx_text = yes
       Wx = Good
       DISPLAY "
Use the sun to your advantage while attacking by keeping
between it and the bogey if possible.  Use your wingman
as much as possible to maintain a good outside scan for
other boyeys
"
BECAUSE "To determine the weather conditions and
issue appropriate warnings, the cloud deck and
visibility must be ascertained";
```

```
RULE 7d
IF    Clouds = None AND
      Visibility = Unlimited
THEN  Wx_text = yes
      Wx = Good
      DISPLAY "
Use the sun to your advantage while attacking by keeping
between it and the bogey if possible.
"
BECAUSE "To determine the weather conditions and
issue appropriate warnings, the cloud deck and
visibility must be ascertained";


RULE 7e
IF    Clouds = High_Cloud_Ceiling AND
      Visibility = Good
THEN  Wx_text = No
      Wx = Good
BECAUSE "To determine the weather conditions and
issue appropriate warnings, the cloud deck and
visibility must be ascertained";


RULE 7f
IF    Clouds = High_Cloud_Ceiling AND
      Visibility = Unlimited
THEN  Wx_text = No
      Wx = Good
BECAUSE "To determine the weather conditions and
issue appropriate warnings, the cloud deck and
visibility must be ascertained";


RULE 7g
IF    Visibility = Poor
THEN  Wx_text = yes
      Wx = Poor
      DISPLAY "
For low clouds or poor visibility, good altitude scan
discipline must be exercised in order to maintain
adequate ground clearance.
"
BECAUSE "To determine the weather conditions and
issue appropriate warnings, the cloud deck and
visibility must be ascertained";
```

```
!This section is used for a bogey
!that does not turn with the fighter

RULE 8a
IF    Bogey_turn=No AND
      Fighter_Under_Radar_Contact=No
THEN  Fighter_Tactic=D
BECAUSE "If the bogey does not turn it is likely
that he is going to launch an air to surface
missile at the carrier";

RULE 8b
IF    Bogey_turn=No AND
      Fighter_Under_Radar_Contact=YES OR
      Fighter_Under_Radar_Contact=Unk
THEN  Fighter_Tactic=E
BECAUSE "If the bogey does not turn it is likely
that he is going to launch an air to surface
missile at the carrier";




!This section determines the bogey and the
!type of weapon he is carrying by getting
!the name of the aircraft and weapon from
!the user and then accessing the database
!files to get data on the performance
!capabilities of both from different fields

RULE 9a
IF      Bogey_Type <> UNKNOWN
THEN    CLOSE c:\data\vpx\aircraft
        GET Bogey_Type = a_design,c:\data\vpx\aircraft,
        a_gnration
        Generation = (a_gnration)

BECAUSE "The bogey's aircraft type will affect the manuever
that the fighter should use.";


RULE 9b
IF      Weapon_Name <> UNKNOWN
THEN    CLOSE c:\data\vpx\weapon
        GET Weapon_Name = wpn_name,c:\data\vpx\weapon,
        wpn_type
        missile_aspect = (wpn_type)
BECAUSE "The system needs to know the type of weapon in
order to determine its capability.";
```

```
!This section determines bogey
!weapon capability by reading
!the missile aspect field from
!the weapon record in the database

RULE 9c
IF      missile_aspect = FWD_QTR_MISSILE
THEN    FQ_Weapon_System = Yes

BECAUSE "The weapon system capability will help determine
the proper manuever to use.";


RULE 9d
IF      missile_aspect = REAR_QTR_MISSILE
THEN    FQ_Weapon_System = No

BECAUSE "The weapon system capability will help determine
the proper manuever to use.";



!This section determines the bogey's
!maneuvering ablility through the use
!of the generation, the airspeed and
!whether he turned or not.  The conclusions
!reached in this section are fictituous and
!do not necessarily reflect how a bogey's
!fighting capability is determined

RULE 10a
IF      Generation<>2 AND
        Bogey_AS=Fast AND
        Bogey_turn=Yes
THEN    Corner_capability=Fair
BECAUSE "This section is fictitious and does
not necessarily reflect how the bogey's
fighting capability is determined";


RULE 10b
IF      Generation=2 AND
        Bogey_AS=Fast OR
        Bogey_AS=Corner AND
        Bogey_turn=Yes
THEN    Corner_capability=Poor
BECAUSE "This section is fictitious and does
not necessarily reflect how the bogey's
fighting capability is determined";
```

```
RULE 10c
IF      Generation <> 2 AND
        Bogey_AS=Corner AND
        Bogey_turn=Yes
THEN    Corner_Capability=Good
BECAUSE "This section is fictitious and does
not necessarily reflect how the bogey's
fighting capability is determined";

RULE 10d
IF      Generation=1 OR
        Generation=4 AND
        Bogey_AS=Slow AND
        Bogey_turn=Yes
THEN    Corner_Capability=Good
BECAUSE "This section is fictitious and does
not necessarily reflect how the bogey's
fighting capability is determined";

RULE 10e
IF      Generation=2 OR
        Generation=3 AND
        Bogey_AS=Slow AND
        Bogey_turn=Yes
THEN    Corner_Capability=Fair
BECAUSE "This section is fictitious and does
not necessarily reflect how the bogey's
fighting capability is determined";



!This section determines the bogey's
!overall combat capability for the
!sytem and again does not necessarily
!reflect the method used in determining
!bogey capability

RULE 11a
IF      Corner_Capability = Good
THEN    Bogey_Capability = Hi
BECAUSE "This section is fictitious and does
not necessarily reflect how the bogey's
fighting capability is determined";

RULE 11b
IF      Corner_Capability = Fair AND
        FQ_Weapon_System = Yes
THEN    Bogey_Capability = Hi
BECAUSE "This section is fictitious and does
not necessarily reflect how the bogey's
fighting capability is determined";
```

```
RULE 11c
IF      Corner_Capability = Fair AND
        FQ_Weapon_System = No
THEN    Bogey_Capability = Med
BECAUSE "This section is fictitious and does
not necessarily reflect how the bogey's
fighting capability is determined";

RULE 11d
IF      Corner_Capability = Poor AND
        FQ_Weapon_System = Yes
THEN    Bogey_Capability = Med
BECAUSE "This section is fictitious and does
not necessarily reflect how the bogey's
fighting capability is determined";

RULE 11e
IF      Corner_Capability = Poor AND
        FQ_Weapon_System = No
THEN    Bogey_Capability = Lo
BECAUSE "This section is fictitious and does
not necessarily reflect how the bogey's
fighting capability is determined";


!This section gives the intercept description
!as determined in the earlier intercept section

RULE 12a
IF    Intercept_type = BVR
THEN  Intercept_tactic = F-pole
      DISPLAY"
You should use tactic {#Intercept_tactic}.
This is an F-pole shot with an escape immediately
following missile impact
"
       Intercept_type = VID;

RULE 12b
IF    Intercept_type = VID AND
      Threat_level = Hi
THEN  Intercept_tactic = Head_on
      DISPLAY"
You should use tactic {#Intercept_tactic}.
This is a head to head intercept executed in conjuction with
airborne radar surveillance to obtain a VID before engaging
"
BECAUSE "Using a stern conversion in a high threat
environment
could force the fighter to turn his back to the threat axis
making it much more difficult to see an incoming bogey or
SAM";
```

```
RULE 12c
IF    Intercept_type = VID AND
      Threat_level <> Hi
THEN  Intercept_tactic = Stern
      DISPLAY"
You should use tactic {#Intercept_tactic}.
This is a stern conversion executed in conjuction with
airborne radar surveillance to obtain a VID before engaging
"
BECAUSE "In a low threat environment it is much less
dangerous for the fighter to face away from the threat
axis";


!This section uses the weather and the
!intercept to determine the overall tactical
!environment


RULE 13a
IF      Intercept_type = VID AND
        Wx = Good OR
        Wx = Fair
THEN    Environment = Good
BECAUSE "For a VID intercept the fighter should
have good visibility conditions to identify the
bogey at the greatest possible distance";


RULE 13b
IF      Intercept_type = VID AND
        Wx = Poor
THEN    DISPLAY"
Extreme caution must be used when engaging a bogey
in poor environmental conditions.  The chances of
collision with a wingman or the bogey are very high
"
         Environment = Good;


RULE 13c
IF      Intercept_type = BVR
THEN    Environment = Good
BECAUSE "If the intercept is BVR, the fighter does
not need to visually identify the target before
firing a missile";
```

```
!This section determines the fighter's
!first best move by using bogey_capability
!syst_stat, and environment


RULE 14a
IF      Bogey_Capability = Hi AND
        Syst_Stat = Good AND
        Environment = Good
THEN    Fighter_Tactic=B CNF 90;


RULE 14b
IF      Bogey_Capability = Med AND
        Syst_Stat = Good AND
        Environment = Good
THEN    Fighter_Tactic=A CNF 90;


RULE 14c
IF      Bogey_Capability = Lo AND
        Syst_Stat = Good AND
        Environment = Good
THEN    Fighter_Tactic=C CNF 90;



!This section describes the tactic
!determined above

RULE 15a
IF      Fighter_Tactic=A
THEN    Tac_Desc = Tac_A
        DISPLAY "
You should use tactic {#Fighter_Tactic}.  This is an
extension of 3-5 seconds followed by a pitch back or pitch
up manuever depending on the bogey's vertical separation.
Be sure to maintain visual contact as this bogey is
generally small and hard to keep track of.
";


RULE 15b
IF      Fighter_Tactic=B
THEN    Tac_Desc = Tac_B
        DISPLAY "
You should use tactic {#Fighter_Tactic}.
This is a hard turn to a one circle fight in order to get
the earliest shot oppurtunity.  This bogey is generally fast
so weapon separation can occur rapidly as can an out of the
envelope situation.
";
```

```
RULE 15c
IF      Fighter_Tactic=C
THEN    Tac_Desc = Tac_C
        DISPLAY "
You should use tactic {#Fighter_Tactic}.
This is a turn to a two circle fight in order to
maintain weapon separation.  This bogey can turn relatively
rapidly so
it may turn into a long engagement.
";

RULE 15d
IF      Fighter_Tactic=D
THEN    Tac_Desc = Tac_D
        DISPLAY "
You should use tactic {#Fighter_Tactic}.
This is a hard turn to engage and chase the
bogey with a shot at the earliest possible time
";

RULE 15e
IF      Fighter_Tactic=E
THEN    Tac_Desc = Tac_E
        DISPLAY "
You should use tactic {#Fighter_Tactic}.
This is a hard turn to engage and chase the
bogey with a shot at the earliest possible time
while maintaining a lookout for incoming missiles
and bogeys.
";

RULE 15f
IF      Fighter_Tactic = F
THEN    Tac_Desc = Tac_F
        DISPLAY"
You should use tactic {#Fighter_Tactic}.
With degraded systems it is advisable to return to the
carrier unless the system can be returned to full up status
by its own self test capabilities.
";


ASK User_Choice: "Please chose the system you would like
to use by moving the light bar to your choice and
pressing ENTER and then END
";
CHOICES User_Choice: ACMS_Tactics_Advisor, Fighter_Database,
QUIT;

ASK Bogey_Type: "What type of aircraft is the bogey?
";
CHOICES Bogey_Type: MiG-19, MiG-23, MiG-21, MiG-29;
```

```
ASK Weapon_Name: "What weapon is the bogey carrying?
";
CHOICES Weapon_Name: AA-2,AA-6,AA-7,AA-10,AA-12;

ASK Bogey_AS: "What is the bogey's airspeed?
";
CHOICES Bogey_AS: Corner,Fast,Slow;

ASK Bogey_turn: "Does the bogey make an engaging turn?
";
CHOICES Bogey_turn: Yes,No;

ASK Exit?: "
Would you like to exit the system?
";
CHOICES Exit?: No, Yes;

ASK Fighter_Under_Radar_Contact: "Is the fighter being
painted by an enemy radar?  Choose Yes, No, or Unk for
unknown
";
CHOICES Fighter_Under_Radar_Contact: Unk,Yes,No;

ASK radar_missile: "What is the condition of your radar
missile system
";
CHOICES radar_missile: Good, Marginal, Poor;

ASK heat_missile: "What is the condition of your heat
seeking missile system?
";
CHOICES heat_missile: Good, Marginal, Poor;

ASK radar: "What is the condition of your radar system?
";
CHOICES radar: Good, Marginal, Poor;

ASK gun: "What is the condition of your gun system?
";
CHOICES gun: Good, Marginal, Poor;

ASK Flight_cont: "What is the condition of your flight
control system?
";
CHOICES Flight_cont: Good, Marginal, Poor;

ASK Wing_syst: "What is your wingman's status?
";
CHOICES Wing_syst: Good, Marginal, Poor;

ASK Fuel_state: "What is the lowest fuel state in your
flight in pounds?
```

```
ASK missile_launch: "Has a missile been launched in the
area?
";
CHOICES missile_launch: No, Yes;

ASK bogeys_sighted: "Have any other flights of enemy
aircraft
been sighted or detected on radar within 10 miles?
";
CHOICES bogeys_sighted: No, Yes;

ASK triple_a: "Are there AAA or SAM sites within 5 miles?
";
CHOICES triple_a: No, Yes;

ASK Bogey_control: "What method of intercept control is in
use by the bogey aircraft:
";
CHOICES Bogey_control: Self, Airborne, Ground;

ASK Rules_of_Engagement: "What Rules of Engagement are
currently in effect?
BVR (beyond visual range) or VID (visual identification
required)
";
CHOICES Rules_of_Engagement: VID, BVR;

ASK Clouds: "What is the ceiling in the area?
";
CHOICES Clouds: Low_Cloud_Deck, High_Cloud_Ceiling, None;

ASK Visibility: "What is the visibility in the area?
";
CHOICES Visibility: Unlimited, Good, Poor;

ASK Number_of_Bogeys: "How many bogeys are being painted by
radar?
";
CHOICES Number_of_Bogeys: 1, 2;

ASK Form_sort: "What formation are the bogeys flying in?
";
CHOICES Form_sort: Stacked_Left, Stacked_Right, Trail,
Combat_Spread;

ASK Radar_contact: "Who has radar contact with the bogey?
";
CHOICES Radar_contact: Fighter, Wing, Both;

ASK Fighter_form: "Where is your wingman located?
";
CHOICES Fighter_form: Right, Left;
```

```
ASK Dist_to_homeplate: "How far are you from homeplate?
";
CHOICES Dist_to_homeplate: Less_than_50, 50_to_100,
100_to_200,
More_than_200;
```

APPENDIX D

SESSION WITH ACMS

Welcome to the **AIR COMBAT MANEUVERING SYSTEM**

ACMS has two subsystems that can be used in conjunction. The ACMS Tactics Advisor is a VP-Expert rule base that can be used as a training aid in the ACM arena. The Advisor will aid in determining na appropriate ACM tactic for a given situation. Due to security considerations it is limited in scope. A series of questions will be asked and a menu of responses will be shown. To make a response you will need to move the light bar to your choice by using the arrow keys, then press the ENTER key, and then press the END key. The system will do the rest.

The Fighter Database is a dBase III+ constructed database containing information on theaters, countries, air forces, fighters and weapons systems. It is also used by the Tactics Advisor in determining a tactic to use.

Please choose the system you would like to use by moving the light bar to your choice and pressing ENTER and then END.

ACMS Tactics Advisor< Fighter Database Qit

What is the condition of your heat seeking missile system?

Good< Marginal Poor

What is the condition of your radar missile system?

Good< Marginal Poor

What is the condition of your gun system?

Good< Marginal Poor

What is the condition of your radar system?

Good< Marginal Poor

What is the condition of your flight control system?

Good< Marginal Poor

What is your wingman's status?

Good< Marginal Poor

What is the lowest fuel state in your flight in pounds?

4500

How far are you from homeplate?

Less than 50 **50 to 100<** 100 to 200

More than 200

Caution should be exercised when engaging the bogey since the distance to homeplate is so great. Your fuel state should be monitored closely.

What is the ceiling in the area?

Low Cloud Deck **High Cloud Ceiling<** None

What is the visibility in the area?

Unlimited **Good<** Poor

Has a missile been launched in the area?

No< Yes

Have any other flights of enemy aircraft been sighted or detected on radar within 10 miles?

No< Yes

Are there AAA or SAM sites within five miles?

No<   Yes

What method of intercept control is in use by the bogey aircraft?

Self   Airborne   Ground<

How many bogeys are being painted by radar?

1   2<

What formation are the bogeys flying in?

Stacked Left   Stacked Right<   Trail

Combat Spread

Who has radar contact with the bogey?

Fighter<   Wing   Both

Where is the wing man positioned?

Right<   Left

The fighter should be the eyeball and the wingman should be the shooter. The shooter should perform a cross-under to get to a good shot position. The shooter heeds to get radar contact as soon as possible with the help of the eyeball if necessary.

Does the bogey make an engaging turn?

Yes<   No

What type of aircraft is the bogey?

MiG-19	MiG-23	**MiG-21<**
MiG-29		

What is the bogey's airspeed?

Corner	**Fast<**	Slow

What weapon is the bogey carrying?

AA-2<	AA-6	AA-7
AA-10	AA-12	

You should use tactic C CNF 90
This is a turn to a two circle fight in order to maintain weapon separation. This bogey can relatively rapidly so it may turn into a long engagement.

Would you like to exit the system?

No	**Yes<**

Press Q to exit the shell

APPENDIX E

GLOSSARY

AAA: anti-aircraft artillery

bogey: an unidentified aircraft

carrier air wing: the complement of aircraft on an aircraft carrier

homeplate: the fighter's base of operations, either an airport or a carrier

loadout: the combination of weapons carried by an aircraft

Pilot's Associate: an integrated cockpit advisory and evaluation system currently under development by the Air Force

Rules of Engagement: the rules in effect pertaining to the intercept and fighting of a bogey

shot envelope: the parameters within which a weapon must be used to ensure a hit on the target

SAM: surface to air missile

weapons free: a fighter aircraft is cleared to fire

weapons tight: a fighter aircraft is not cleared to fire

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